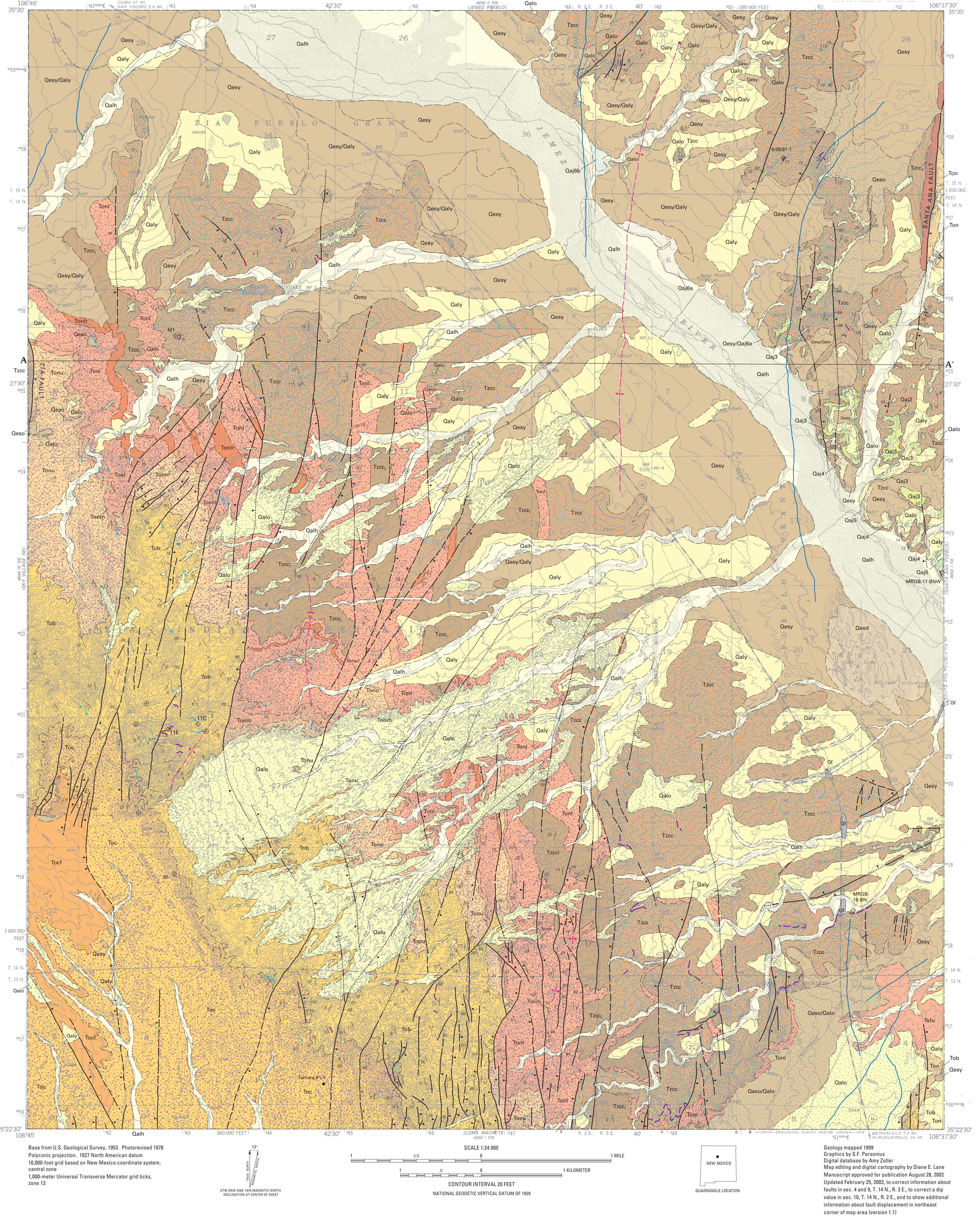
U.S. DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY

MISCELLANEOUS FIELD STUDIES MAP MF–2404
Version 1.1



Base from U.S. Geological Survey, 1953. Photorevised 1978
Polyconic projection. 1927 North American datum
10,000-foot grid based on New Mexico coordinate system, central zone
1000-meter Universal Transverse Mercator grid ticks, zone 13

SCALE 1:24 000
CONTOUR INTERVAL 20 FEET
NATIONAL GEODETIC VERTICAL DATUM OF 1929

Geology mapped 1999
Graphics by S.F. Personius
Digital database by Amy Zoller
Map editing and digital cartography by Diane E. Lane
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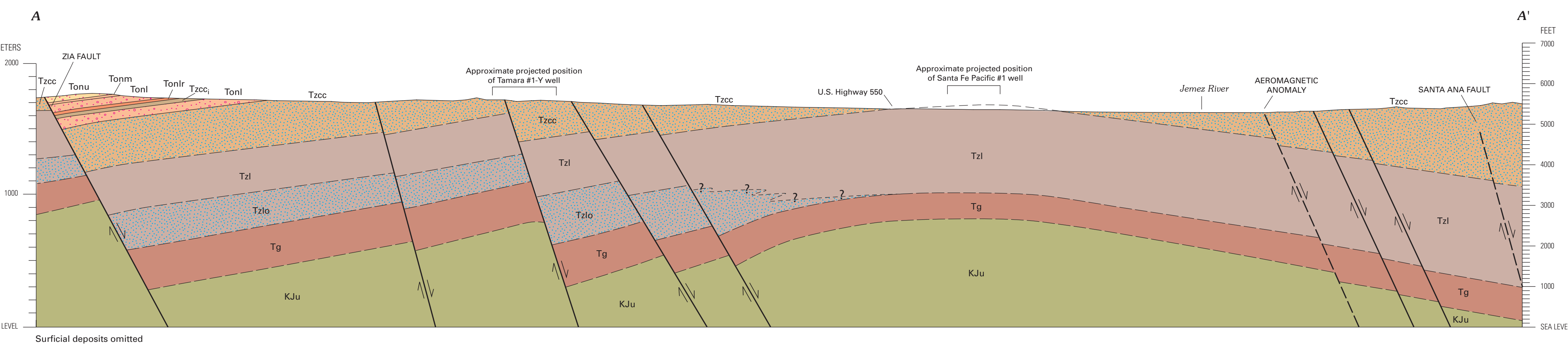
Updated February 25, 2003, to correct information about faults in sec. 4 and 5, T. 14 N., R. 3 E., to correct a dip value in sec. 11, T. 14 N., R. 2 E., and to show additional information about fault displacement in northeast corner of map area (version 1.1)



Surficial deposits omitted

GEOLOGIC MAP OF THE BERNALILLO NW QUADRANGLE, SANDOVAL COUNTY, NEW MEXICO

By

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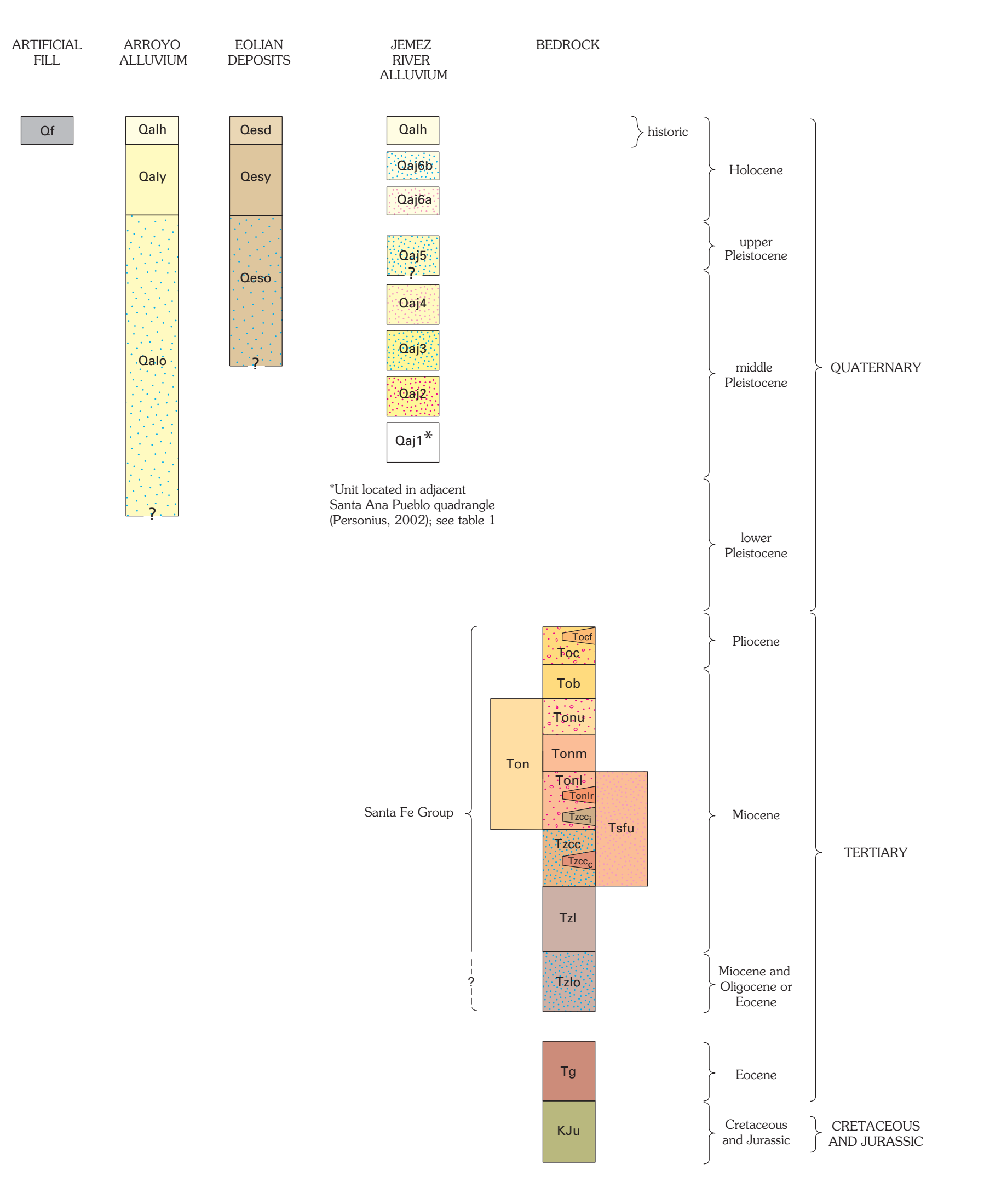
2002

CORRELATION OF MAP AND SUBSURFACE UNITS



*Unit located in adjacent Santa Ana Pueblo quadrangle (Personius, 2002); see table 1

DESCRIPTION OF MAP AND SUBSURFACE UNITS

[Grain size descriptions are based on field estimates and follow Udden-Wentworth scale for clastic sediment (Udden, 1914; Wentworth, 1922); sands are classified according to Pettijohn and others (1987). The term "clast(s)" refers to grain size fraction greater than 2 mm in diameter; clast percentages are based on percent volume and were estimated in field with aid of percentage charts. Colors of unconsolidated sediment are based on visual comparison of dry samples with Munsell soil color charts (Munsell Color, 1994). Surficial units are only shown on map if estimated to be at least 1 m thick. Soil-horizon designations and descriptive terms follow those of Soil Survey Staff (1992), Birkeland and others (1991), and Birkeland (1999)]

Qf **Artificial fill (historic)—**Locally derived and imported aggregate materials used for construction purposes. Primarily used for highway fills along U.S. Highway 550 and access road to old Santa Ana Pueblo. Sparsely vegetated to revegetated; no soil development. Thickness 1–10 m

ARROYO ALLUVIUM

Qalh **Active channel alluvium (historic)—**Light-yellowish-brown to very pale brown (10YR 6–7/4), fine to coarse sand, silty sand, pebbly sand, and less common sandy pebble, cobble, and boulder gravel; gravel is poorly to moderately sorted, massive to well bedded, with local crossbedding; sand is poorly sorted to well sorted, subrounded, and lithic and feldspathic in composition. Gravel clast compositions reflect local geologic units exposed in drainage area. Commonly forms channel fills and bars. Confined to present arroyo channel floors and bed of Jemez River. Unit commonly includes small areas of active sand dunes (unit **Qesd**) and young eolian sand (unit **Qesy**). Sparsely vegetated (seasonal inundation) to unvegetated; no soil development. Thickness 1 to >5 m

Qaly **Younger arroyo alluvium (Holocene)—**Light-yellowish-brown, very pale brown, to light-gray (10YR 6–7/4), fine to coarse sand, silty sand, pebbly sand, mud, and sandy pebble, cobble, and boulder gravel; massive to well bedded, with local crossbedding. Gravel clast compositions reflect local geologic units exposed in drainage area; clasts are chiefly reworked from underlying Santa Fe Group rocks, which primarily are derived from source areas to northwest (Sierra Nacimiento and Jemez Mountains); common lithologies include Precambrian pink granitic rocks, petrified wood, Pedernal Chert Member of Abiquiu Formation, Paleozoic chert and limestone, Mesozoic sandstone, and intermediate to mafic volcanic rocks. Gravels are mostly subrounded, poorly to moderately sorted, and commonly form 0.5- to 1-m-thick, channel-shaped or lenticular beds. Unit underlies low terraces along major arroyos and Jemez River, 2–8 m above adjacent channels. Unit commonly includes small areas of active sand dunes (unit **Qesd**) and younger eolian sand (unit **Qesy**). Sparsely vegetated. Some low terraces along major arroyos contain charcoal-rich hearth sites. Soil development is minimal, usually with only minor oxidation, thin A horizons, and stage I Bk horizons. Thickness 1–5 m

Qalo **Older arroyo alluvium (Holocene to lower(?) Pleistocene)—**Light-brown, light-yellowish-brown, to brownish-yellow (10YR 6/4–6) to light-gray (10YR 7/2), fine to coarse sand, silty sand, pebbly sand, and sandy pebble, cobble, and boulder gravel; poor to moderately sorted, massive to well bedded, with uncommon crossbedding. Gravel clast compositions reflect local geologic units exposed in drainage area: south of Jemez River, clasts are chiefly reworked from underlying Santa Fe Group rocks, which primarily were derived from outcrops to northwest (Sierra Nacimiento and Jemez Mountains); common lithologies and percentages include >50 percent pink granite, <5 percent petrified wood, <15 percent Paleozoic limestone and brown chert, 2–25 percent Mesozoic sandstone, 2–10 percent Pedernal Chert Member of Abiquiu Formation, 5–15 percent basalt, 5–25 percent intermediate volcanic rocks, and 1–5 percent reworked petrocalcic soil fragments; north of Jemez River, clasts are chiefly basalt from Santa Ana Mesa. Unit underlies remnants of alluvial aprons and terraces along major arroyos, 8–40 m above adjacent channels. Some deposits are thin and overlie straths cut in underlying bedrock, but other deposits along larger drainages form 10- to 20-m-thick fills. Unit commonly includes small areas of eolian sand (units **Qesy** and **Qeso**). Deposits at mouths of major arroyos interfinger with and (or) overlie deposits of Jemez River (units **Qaj2**–**Qaj6**). Soil development is variable, but stage I through stage III Bk horizons are common in lower deposits, and Bt horizons and stage III–IV Bk horizons are common in older, higher deposits. Correlative with unit **Qvd** of Personius and others (2000) in the Loma Machete quadrangle. Thickness 1–20 m

EOLIAN DEPOSITS

Qesd **Active sand dunes (historic)—**Very pale brown to light-yellowish-brown (10YR 6–7/4), loose, subrounded, well-sorted, crossbedded, very fine to coarse feldspathic sand. Forms extensive dune fields along south side of Jemez River. Small areas of active dunes are included in younger eolian sand (unit **Qesy**). Thickness 1–5 m

Qesy **Younger eolian sand (Holocene)—**Very pale brown to light-yellowish-brown (10YR 6–7/4), subrounded to subangular, moderately sorted to well sorted, very fine to coarse feldspathic sand that is massive or horizontal, wavy, to cross laminated. Primarily deposited as thin sheets, coppice dunes, and small dune fields along the Jemez River and downwind (east) of large arroyos and in areas underlain by poorly consolidated bedrock of unit **Tzcc**. Soil development is minimal, usually with only minor oxidation, but may contain stage I Bk horizons. Thickness 1–5 m

Qeso **Older eolian sand (Holocene to middle(?) Pleistocene)—**Light-brown to light-brownish-gray (7.5 YR 6/4 and 10YR 6/2), massive to horizontal to cross-stratified, moderately sorted to well sorted, very fine to coarse sand with subordinate silt and clay. Primarily deposited as sheets and small dune fields on broad upland surfaces throughout the map area. Commonly overlies older fan surfaces underlain by deposits of older alluvium (unit **Qalo**). Extensive deposits, such as those west of the Santa Ana fault and in the southeast corner of the quadrangle, commonly consist of multiple deposits separated by buried soils. Surface and buried soils are characterized by extensive bioturbation, oxidation, and the formation of stage II–III Bk and Btk horizons. Thickness 1–5 m

JEMEZ RIVER ALLUVIUM

Jemez River alluvial deposits were mapped concurrently in the Bernalillo NW and Santa Ana Pueblo (Personius, 2002) quadrangles. Seven map units were identified in these two quadrangles, but all units are not present in both quadrangles. Alluvial units from both quadrangles are included in the "Correlation of Map and Subsurface Units" to aid in unit correlation between quadrangles. To aid in regional correlation, table 1 includes probable correlations with Jemez River alluvial units mapped by others upstream from the Bernalillo NW quadrangle

Qaj6b **Alluvium 6b of Jemez River (Holocene)—**Light-yellowish-brown (10YR 6/4) fine sand, including pale-brown (10YR 6/3), 10-cm-thick interbeds of sandy silt and rare pebbly zones. Deposits underlie fill terrace 4 m above modern channel at mouth of Arroyo Arenoso on north side of Jemez River, but also underlie terraces covered with eolian sand (units **Qesd** and **Qesy**) on south side of river. Correlative with units **Qt9** deposits of Rogers (1996) and Rogers and Smartt (1996), and with unit **Qt6** of Formento-Trigilio and Pazzaglia (1996, 1998), Formento-Trigilio (1997), Pazzaglia (1998), and Pazzaglia and others (1998), mapped upstream of quadrangle, and with upper part of unit **Qaj6** of Personius (2002) mapped downstream of quadrangle (table 1). Thickness >4 m

Qaj6a **Alluvium 6a of Jemez River (Holocene)—**Light-yellowish-brown (10YR 6/4) fine sand, and reddish brown (5YR 5/3) sandy silt. Charcoal-rich in places. Upper part has weak soil development (20-cm-thick Bw horizon). Deposits underlie fill terrace about 6 m above modern channel south of mouth of Arroyo Arenoso on north side of Jemez River, but also underlie broad terrace covered with eolian sand (units **Qesd** and **Qesy**) on south side of river. Correlative with units **Qt7** and **Qt8** deposits of Rogers (1996) and Rogers and Smartt (1996), and with unit **Qt5** of Formento-Trigilio and Pazzaglia (1996, 1998), Formento-Trigilio (1997), Pazzaglia (1998), and Pazzaglia and others (1998), mapped upstream of quadrangle, and with lower part of unit **Qaj6** of Personius (2002) mapped downstream of quadrangle (table 1). Thickness >6 m

Qaj5 **Alluvium 5 of Jemez River (upper to middle(?) Pleistocene)—**Varicolored sand, pebbly sand, pebble and cobble gravel, and silty clay. Upper part consists of about 15 m of yellowish-brown, fine to medium sand and pebbly sand, interbedded with moderately sorted to well sorted pebble and cobble gravel in channel fills 1–2 m thick, and minor thin (10-cm-thick) beds of mottled red and green silty clay. Gravel clasts are subangular to round and well imbricated, show south-southeast (140°–180°) transport directions, and are chiefly pink granite, petrified wood, Paleozoic limestone, Mesozoic sandstone, Pedernal Chert Member of Abiquiu Formation, and intermediate to mafic volcanic rocks, consistent with source areas to northwest. Contains a few charcoal fragments and reworked pumice pebbles in pebbly sand beds near base of upper part; pumice chemically correlates with 1.6-Ma (Izett and Obradovich, 1994) lower Bandelier Tuff (sample locality MRGB–17–BNW; A. Sarna-Wojcicki, written commun., 1998). Lower part consists of at least 3 m of mottled red and green silty clay in beds 10–50 cm thick; lower unit contains common crystals of authigenic gypsum as much as 20 cm in diameter. Well-developed bedding, clast lithologies, rounding, and sorting indicate deposition by Jemez River. Exposures are conformably overlain in places by 1–2 m of basalt-rich cobbly arroyo alluvium (unit **Qalo**) containing stripped, stage II–III Bk horizons; lower contact is not exposed but extends at least to present level of Jemez River channel. In some places unit appears to be inset into, and thus postdates, terrace underlain by alluvium of unit **Qaj4**. Preserved as irregular remnants underlying arroyo fan surfaces north of Jemez River. No clearly correlative alluvial deposit has been described upstream (Formento-Trigilio and Pazzaglia, 1996, 1998; Rogers, 1996; Rogers and Smartt, 1996; Pazzaglia, 1998; Pazzaglia and others, 1998), although the unit may be correlative with a minor strath terrace fill (unit **Qt 5** of Rogers, 1996, and Rogers and Smartt, 1996; unit **Qt4a** of Formento-Trigilio, 1997, and Formento-Trigilio and Pazzaglia, 1998) in the upper Jemez River drainage (F.J. Pazzaglia, oral commun., 2001) (table 1). The unit is correlative with unit **Qaj5** of Personius (2002), mapped downstream of quadrangle. Thickness >15 m

Qaj4 **Alluvium 4 of Jemez River (middle Pleistocene)—**Silt, pebbly sand, and sandy pebble and cobble gravel; moderately sorted and moderately to well bedded. Clasts are subangular to round and well imbricated, show southeast (110°–120°) transport directions, and consist chiefly of pink granite, petrified wood, Paleozoic limestone, Mesozoic sandstone, Pedernal Chert Member of Abiquiu Formation, and intermediate to mafic volcanic rocks, consistent with source areas to northwest. Unit well preserved as 4- to 7-m-thick fill deposits underlying multiple(?) terrace remnants north of Jemez River. Unit commonly consists of 2–4 m of pebbly sand sandwiched between 1- to 3-m-thick pebble and cobble gravel deposits. Deposits overlie a bedrock strath 6–12 m above present channel of Jemez River and are in turn overlain by 1–4 m of basalt-rich, angular cobble and boulder gravel (unit **Qalo**) derived from Santa Ana Mesa. Correlative with unit **Qt5a** deposits of Pazzaglia (1998) and Pazzaglia and others (1998), and may be correlative with unit **Qt4a** of Formento-Trigilio and Pazzaglia (1996, 1998) and Formento-Trigilio (1997), and with unit **Qt5** of Rogers (1996) and Rogers and Smartt (1996), mapped upstream of quadrangle (table 1). Thickness 4–7 m

Qaj3 **Alluvium 3 of Jemez River (middle Pleistocene)—**Pebbly sand and sandy pebble and cobble gravel; moderately sorted, moderate to well bedded. Clasts are subangular to round and well imbricated, show southeast (110°–120°) transport directions, and consist chiefly of pink granite, petrified wood, Paleozoic limestone, Mesozoic sandstone, Pedernal Chert Member of Abiquiu Formation, intermediate to mafic volcanic rocks, consistent with source areas to northwest. Unit well preserved as 4- to 10-m-thick fill deposits underlying prominent terrace remnants north of Jemez River. Deposits overlie a bedrock strath about 30 m above present channel of Jemez River and are in turn overlain by 1–6 m of basalt-rich, angular cobble and boulder gravel (unit **Qalo**) derived from Santa Ana Mesa. Correlative with unit **Qt4** deposits of Rogers (1996) and Rogers and Smartt (1996), Formento-Trigilio and Pazzaglia (1996, 1998), Formento-Trigilio (1997), Pazzaglia (1998), and Pazzaglia and others (1998), mapped upstream of quadrangle, and with unit **Qaj3** of Personius (2002) mapped downstream of quadrangle (table 1). Thickness 4–10 m

Qaj2 **Alluvium 2 of Jemez River (middle Pleistocene)—**Sandy pebble and cobble gravel; moderately sorted and moderately to well bedded. Clasts are subangular to round and well imbricated, show southeast transport directions, and are dominated by rocks that are common in source areas to northwest (Sierra Nacimiento and Jemez Mountains). Unit poorly preserved as 1- to 2-m-thick deposits in two small hills along eastern edge of the quadrangle, north of Jemez River. Deposits overlie bedrock straths 50–60 m above present channel of Jemez River, and commonly are in turn overlain by 1–2 m of basalt-rich angular cobble and boulder gravel (unit **Qalo**) derived from Santa Ana Mesa. Probably correlative with unit **Qt3** deposits of Rogers (1996), Rogers and Smartt (1996), Formento-Trigilio and Pazzaglia (1996, 1998), Formento-Trigilio (1997), Pazzaglia (1998), and Pazzaglia and others (1998), mapped upstream of quadrangle (table 1); unit **Qt3** deposits are inset 30–60 m below deposits that contain Lava Creek B ash, so unit **Qaj2** deposits are inferred to be younger than the ≈640 ka age (Lanphere and others, 2002) of these older deposits. Preserved thickness 1–2 m

BEDROCK

Santa Fe Group

Significant revisions of the Santa Fe Group have recently been proposed by Koning and others (1998) and Connell and others (1999) in the adjacent Cerro Conejo quadrangle. However, this nomenclature is preliminary, and other recent studies have suggested alternative terminology (for example, Pazzaglia and others, 1999; Tedford and Barghoorn, 1999). Herein we retain most of the proposed stratigraphic revisions of the Santa Fe Group of Connell and others (1999) because the reference sections are located nearby, but our usage should not be interpreted as an endorsement for or against the use of this stratigraphic terminology outside of the Bernalillo NW quadrangle

Arroyo Ojito Formation

Toc **Ceja Member of Connell and others (1999) (Pliocene)—**Pinkish-gray (7.5YR 6/2) sandy conglomerate interbedded with reddish-yellow (5YR–7.5YR 6/6) to yellowish-red (5YR 5/8) sandstone and reddish-brown mudstone, with minor (<3 percent) beds of very pale brown to pale-yellow (2.5Y–10YR 7/4) sandstone; unit generally very thin to medium bedded. Conglomerate occurs in lenticular beds and is commonly moderately sorted. Sandstone is fine to coarse grained, subangular to subrounded, and feldspathic in composition. As a whole, unit is poorly to moderately sorted and has <10 percent silt and clay. The conglomerate in the Ceja Member is distinct in that it consists chiefly of pink granite and white Pedernal Chert Member of Abiquiu Formation (40–70 percent and 10–25 percent, respectively); other clasts include 2–8 percent basalt, 1–3 percent quartzite, 3–5 percent rhyolite, 2–5 percent limestone, and varying proportions of sandstone. Intermediate volcanic and hypabyssal clasts are rare (usually <10 percent) and brown chert is very rare. Conglomerate is chiefly pebbles and generally contains 5–10 percent cobbles and <5 percent boulders. Maximum observed boulder diameter is 1 m. Paleocurrent direction (measured in three paleo-channels) is to the southeast, and clast provenance is likely the western Jemez Mountains and eastern Sierra Nacimiento. Ceja Member unconformably overlies Loma Barbon Member with local angular discordance of 0°–5°. In sec. 3, T. 13 N., R. 2 E., ≈35 m of pinkish-gray conglomerate and reddish-yellow sandstone is overlain by 26–33 m of 40–60 percent reddish-yellow (5YR–7.5YR 6/6) sandstone and gravelly sandstone, 5–15 percent red (2.5YR 4/6) and light-yellowish-brown (2.5Y 6/4) mud, and approximately 35 percent light yellowish-brown (10YR 6/4) sand with 3 percent pebbles. Top of Ceja Member has ≈2-m-thick calcic soil horizon with stage V carbonate morphology, generally preserved only where overlain by unit **Tocf**. Unit is poorly to moderately exposed. Ceja Member correlates with units **QTsug** and **Tsus** in the adjacent Loma Machete quadrangle (Personius and others, 2000) and also roughly correlates with undifferentiated upper unit of Cochiti Formation of Manley (1978). Mapped as uppermost gravel of Santa Fe Group by Spiegel (1961) and as Ceja Member of Santa Fe Formation by Kelley (1977). Blancan vertebrate fossils (Wright, 1946; Tedford, 1981; Morgan and Lucas, 1999), and K/Ar and ^{40}Ar/^{39}Ar ages of 3–4 Ma on interbedded basalt flows (Maldonado and others, 1999) have been described in outcrops of Ceja Member elsewhere in Albuquerque basin. Three reworked basalt clasts from an outcrop in southwestern part of quadrangle (sample location 8h) yielded approximate ^{40}Ar/^{39}Ar ages of 6.5–8 Ma (table 2), which provide maximum limiting ages for this part of unit **Toc**. These limited data support a Pliocene age of deposition. Thickness 30–70 m

Tocf **Fault-related rocks in Ceja Member of Connell and others (1999) (Pliocene)—**Light-yellowish-brown to very pale brown to pale-yellow (10YR 6–7/4 and 2.5Y 7/4), thin to medium-, tabular-bedded mudstone and very fine grained to medium-grained, moderately sorted to well sorted, subrounded to subangular feldspathic sandstone. Lenticular, thin- to medium- bedded sandy pebble conglomerate and pebbly sandstone beds compose <5 percent by volume. Unit consists of alluvial, eolian, and colluvial sediment in wedge-shaped deposits abutting faults. Unit is well exposed only in southwest corner of quadrangle, where soil-bounded wedges are not as distinct as in adjacent Cerro Conejo quadrangle (Koning and others, 1998) to west. Unit is capped in places by a soil consisting of a ≈30-cm-thick Bt horizon overlying a 50- to 100-cm-thick stage II to III calcic horizon; locally, soil is overlain by at least 1 m of light-yellowish-brown (10YR 6/4) silt and pebbly, fine to coarse sand. Unit roughly correlates with Pantadeleon Formation of Connell and others (1999) in adjacent Cerro Conejo quadrangle (Koning and others, 1998). However, unit is not formally named herein because the proposed Pantadeleon Formation of Connell and others (1999) also is applied to widespread eolian, alluvial, and colluvial sediment on the Llano de Albuquerque that may be difficult to differentiate unless their association with normal faults is demonstrated; such reliance on depositional environment is not allowed in the definition of formal stratigraphic units (North American Commission on Stratigraphic Nomenclature, 1983). Lack of inclusion of the Pantadeleon Formation in a recent synthesis of Albuquerque basin stratigraphy (Connell, 2001) suggests this term is undergoing revision. A lens of volcanic ash in correlative rocks in adjacent Cerro Conejo quadrangle shows good chemical correlation with 3.28-Ma Nomlaki Tuff Member of Tuscan and Tahama Formations of northern California (A. Sarna-Wojcicki, written commun., 1998, in Connell and others, 1999). Unit also contains sediment mapped as unit Qad by Manley (1978), so faulting-related sedimentation may have extended into the Quaternary. Maximum thickness 30 m

Tob **Loma Barbon Member of Connell and others (1999) (Pliocene to upper Miocene)—**Reddish-yellow to light-brown sandstone, muddy or silty sandstone, and mudstone beds containing ≤10 percent conglomerate; unit coarsens upward. Sandstones are pink to reddish yellow (range of 7.5YR 7/4, 5–10YR 5–6/6, and 5YR 7/4) but become more yellow in SW¼ sec. 34, T. 14 N., R. 2 E. Sandstones are very fine grained to coarse grained (commonly fine to medium grained), moderately sorted to well sorted, subangular to subround, and feldspathic in composition, and they occur in tabular to lenticular, thin to medium beds. Conglomerate occurs in lenticular beds and fills channels. Pebble and minor cobble conglomerate consists of 15–50 percent pink granite, 5–25 percent white feldspathic to quartzose sandstone along with reddish-tan quartzose sandstone, 5–20 percent Pedernal Chert Member of Abiquiu Formation, 2–5 percent basalt, ≤5 percent quartzite, and 15–40 percent intermediate volcanic and hypabyssal rocks. Conglomerate is abundant (10–15 percent by volume) immediately west of major fault in sec. 22, T. 14 N., R. 2 E. but is rare along southern margin of quadrangle (1–2 percent by volume). Channels commonly trend 145°–170°. Mudstone is generally reddish brown, brown, reddish yellow, dark yellowish brown, and yellowish red (range of 2.5YR 6–7/4, 5YR 5/6, 5YR 4–5/4, 7.5YR 4–7/4, 7.5YR 6/6, 10YR 4–6/4) and consists of very thinly to medium bedded, tabular sandy claystone that comprises <20 percent by volume. A 30- to 80-cm-thick conglomerate bed composed almost exclusively of reworked gray pumice pebbles is found ≈15 m below contact of units **Toc** and **Tob** in sec. 2, T. 13 N., R. 2 E.; pumice has 2–5 percent pyroxene or hornblende phenocrysts. Lower in section, a ≈4-m-thick channel deposit of conglomerate and sandstone is located in NE¼ sec. 28, T. 14 N., R. 2 E., and NE¼ NW¼ sec. 2, T. 13 N., R. 2 E.; upper 10–100 cm of this deposit is mostly composed of fluvially reworked pumice pebbles as long as 3 cm; lower part of deposit consists of 1- to 4-m-thick interval of indurated sandstone and conglomerate. A sample of pumice from the pumice-bearing channel deposit in sec. 28 (sample locality 11E) yielded an ^{40}Ar/^{39}Ar age of 7.02±0.06 Ma (table 2); a hornblende-bearing pumice clast from a bouldery channel deposit about 20 m stratigraphically below the pumice-rich channel deposit in sec. 28 yielded an ^{40}Ar/^{39}Ar age of 7.38±0.03 Ma (sample locality 11C, table 2). These data provide maximum limiting ages for this part of unit **Tob**. Upper 9–15 m of unit **Tob** consists of light-yellowish-brown to brownish-yellow (10YR 6/4–6), fine- to medium-grained, well-sorted, thin- to medium-bedded sandstone containing 2–25 percent, brown (7.5YR 5–6/4), thin mudstone beds and minor pebble and boulder conglomerate. The unit commonly sharply overlies upper part of Navajo Draw Member (unit **Tonu**), and lower contact may be locally scoured. However, in NE¼ sec. 35, T. 14 N., R. 2 E., contact of units **Tob** and **Tonu** appears conformable and gradational over thickness of 1–2 m. Unit is moderately exposed to well exposed, except upper part, which is loose and poorly exposed. Correlates with unit **Tsums** on the adjacent Loma Machete quadrangle (Personius and others, 2000), and also roughly correlates with undifferentiated middle unit of Cochiti Formation of Manley (1978). Mapped as western facies of unnamed upper formation of Santa Fe Group by Spiegel (1961) and as undivided Santa Fe Formation by Kelley (1977). In adjacent Cerro Conejo (Koning and others, 1998; Connell and others, 1999) and Bernalillo (Connell and others, 2000) quadrangles, ashes from the middle part of Loma Barbon Member yield ^{40}Ar/^{39}Ar ages of 6.8 Ma, indicating an upper Miocene age for middle part of unit. Possibly correlative deposits may underlie 2.5- to 2.6-Ma (Bachman and Mehnert, 1978; Smith and Kuhle, 1998) basalts of Santa Ana Mesa (Cather and Connell, 1998; Connell and others, 1999, 2000); such correlations support a Pliocene age for upper part of unit. Thickness 120–180 m

Ton **Navajo Draw Member of Connell and others (1999) (upper Miocene)—**Undifferentiated member consists of four subunits dominated by yellow to light-yellowish-brown to very pale brown sandstone, silty sandstone, mudstone, and pebble conglomerate beds. Unit is 10–30 percent thin to thick, tabular-bedded sandy mudstone. Sandstones are thinly bedded to medium bedded and lenticular or tabular, subangular to subround, well sorted, and feldspathic to quartz-rich feldspathic in composition. Conglomerate volume decreases northwest to southeast from ≈5 percent to <0.5 percent and occurs primarily in lenticular to channel-shaped beds. Clast imbrication, channel trends, and cross-stratification within conglomerate beds indicate southeast transport directions. Conglomerate clasts consist of 1–3 percent red to yellow siltstone, 10–35 percent brown chert, 3–25 percent sandstone, 5–15 percent quartz or quartzite, <2 percent petrified wood, ≤5 percent pink granite,≤5 percent basalt, <5 percent rhyolitic tephra, trace Pedernal Chert Member of Abiquiu Formation, and >30 percent intermediate to felsic volcanic rocks. Unit is moderately exposed. Navajo Draw Member has gradational, interfingering contact with underlying Cerro Conejo Member of Zia Formation (unit **Tzcc**). Along southern margin of quadrangle (SW¼ SW¼ sec. 6, T. 13 N., R. 3 E.), a body of lower Navajo Draw Member (unit **Tonl**) pinches out within unit **Tzcc**. The gradational zone encompasses lower ≈100–150 m of Navajo Draw Member along western margin of map area and lower ≈150–300 m in south-central part of map area. The gradational zone is similar to unit **9a** of the Navajo Draw Member in adjacent Cerro Conejo quadrangle (Koning and others, 1998; Connell and others, 1999). The lower Navajo Draw Member contact is placed at the lowest occurrence of pale-yellow (2.5Y 7/4) to light-yellowish-brown (10YR 6/4), medium bedded to thickly bedded mudstone. In some places, tongues or lenses of Cerro Conejo Member of Zia Formation (unit **Tzcc$_i$**) are mapped above this contact. Unit correlates with unit **Tsmms** and upper part of unit **Tslms** in the adjacent Loma Machete quadrangle (Personius and others, 2000); the upper (unit **Tonu**), middle (unit **Tonm**), and lower (unit **Tonl**) subunits probably correlate with undifferentiated upper yellow zone, middle red zone, and lower reddish-yellow to pink zone of lower unit of Cochiti Formation of Manley (1978). Mapped as red member of unnamed lower formation of Santa Fe Group by Spiegel (1961) and as Zia Member of Santa Fe Formation by Kelley (1977). The Navajo Draw Member lacks diagnostic fossils, but interpreted ages of the overlying and underlying rocks indicate a late Miocene age. Total thickness in western part of map are (sec. 16, 17, 8, and 9 of T. 14 N., R. 2 E.), including interbedded Cerro Conejo sandstone (unit **Tzcc$_i$**), is about 225–275 m. Total thickness in Davis Oil Co. Tamara #1–Y exploratory well near southern map area boundary is about 200 m (Connell and Koning, 2001); thickness appears to increase across a major down-to-the-east fault just east of well. Total thickness near south-central part of quadrangle (sec. 25 and 36, T. 14 N., R. 2 E.), including interbedded Cerro Conejo sandstone (unit **Tzcc$_i$**), is about 450–600 m. In Rio Rancho #18 water well in the northeastern part of Loma Machete quadrangle, correlative unit **Tsmms** is about 300 m thick (Personius and others, 2000); this thickness may include interbedded Cerro Conejo sandstone (unit **Tzcc$_i$**) (S.D. Connell, oral commun., 2001). Mapped as undifferentiated Navajo Draw Member (unit **Ton**) in northeastern part of map area in structurally complex zone in hanging wall of Santa Ana fault and in adjacent Santa Ana Pueblo quadrangle (Personius, 2002); rocks here are mostly pink (5YR 7/3), very pale brown (10YR 8/2) to light-gray (10YR 7/1) fine- to medium-grained sandstone, interbedded with minor pale-red (2.5 YR 7/3) to red (2.5 YR 5/6) siltstone and claystone and with rare, thin pebble to cobble beds of pumice and rhyolitic nonwelded tuff. South of Jemez River, Navajo Draw Member is subdivided into the four subunits described below

Tonu **Upper part of Navajo Draw Member of Connell and others (1999) (upper Miocene)—**Upper interval consists of pale-yellow to very pale brown (2.5Y–10YR 7/4), very fine grained to medium grained, thinly to thickly tabular bedded, well-sorted, subangular to subrounded, quartz-rich feldspathic sandstone and ~5 percent pale- yellow (2.5Y 7/4) to light-yellowish-brown (10YR 6/4), thin bedded to very thin bedded mudstone. Also contains rare conglomerate with <10 percent pink granite clasts. Mud-rich lower interval consists of 6–15 m of yellow to olive-yellow (10YR–2.5Y 6–7/6), fine- to medium-grained sandstone and minor siltstone, interbedded with 10–35 percent light-yellowish-brown (2.5Y–10YR 6/4) sandy mudstone. In hanging wall of Zia fault in sec. 8, T. 14 N., R. 2 E., unit consists of distinct orange-brown, very thin bedded to medium bedded, fine-grained sandstone and mudstone. Thickness 50–90 m in western part of quadrangle and 50–120 m in sec. 36, T. 14 N., R. 2 E.

Tonm **Middle part of Navajo Draw Member of Connell and others (1999) (upper Miocene)—**Reddish, fine- to coarse-grained, moderately sorted to well sorted, subangular to subrounded feldspathic sandstone, pebble conglomerate, and mudstone. Conglomerate contains 2–30 percent pink granite, generally lacks yellow and red siltstone clasts, and contains <10 percent brown chert. Thickness 6–9 m in western part of map area and 12–18 m in west-central part of map area. Near southern edge of map area, unit is only 2–3 m thick and consists of medium-grained sandstone and clayey mudstone

Tonl **Lower part of Navajo Draw Member of Connell and others (1999) (upper Miocene)—**Pale-yellow (2.5Y 7/4) to very pale brown to light-yellowish-brown (10YR 6–8/4), fine- to medium-grained, moderately sorted to well sorted, subangular to subrounded feldspathic to quartz-rich feldspathic sandstone, 5–50 percent mudstone, and subordinate pebble conglomerate. Bedding is commonly thin to thick and tabular or lenticular, but sandstone is locally cross laminated, with foresets generally <30 cm in height. Conglomerate beds are more common near top and bottom of unit and consist of 25–35 percent chert, 15–35 percent quartz, and 35–55 percent intermediate volcanic rocks. Tongues or lenses of Cerro Conejo Member of Zia Formation (unit **Tzcc$_i$**) are interstratified in lower part of Navajo Draw Member across quadrangle. Thickness about 150–200 m in western part of map area (NW¼ sec. 9, T. 14 N., R. 2 E.); thickness of 400–500 m in south-central part of map area (SE¼ sec. 25 and 36, T. 14 N., R. 2 E.) includes interstratified units **Tonlr** and **Tzcc$_i$**

Tonlr **Red zone in lower part of Navajo Draw Member of Connell and others (1999) (upper Miocene)—**Distinct reddish, thin- to medium-bedded sandstone and mudstone intervals that lack conglomerate, interbedded in unit **Tonl**. Paleocurrent indicators show southwest and southeast transport directions. Deposits are most common near center and northwestern parts of quadrangle and are rare along southern quadrangle boundary

Tsfu **Santa Fe Group, undivided (Miocene)—**Sedimentary rocks correlative with Santa Fe Group, mapped where surface access was restricted in southeastern part of quadrangle. Probably consists of lowermost Navajo Draw Member of Arroyo Ojito Formation (units **Tonl** or **Tonlr**) and Cerro Conejo Member of Zia Formation (unit **Tzcc**). Thickness unknown

Zia Formation

Tzcc **Cerro Conejo Member of Connell and others (1999) (upper and middle Miocene)—**Pink to very pale brown (7.5YR–10YR 7/4), fine- to coarse-grained, moderately sorted to well sorted, subrounded lithic to feldspathic sandstone and light-reddish-brown (5YR 6/4), clay-rich muddy sandstone. Muddy sandstones are generally thinly bedded and comprise ≤5 percent by volume. Distinctive beds and cylindrical bodies of calcite-cemented, indurated sandstone make up <10 percent by volume. Fossils collected in correlative rocks in the quadrangle and adjacent Cerro Conejo quadrangle (Tedford, 1981; Tedford and Barghoorn, 1997, 1999) and ash ages described below indicate a middle Miocene age for most of unit. Cerro Conejo Member correlates with Zia Sand of Manley (1978) and middle and lower parts of unit **Tslms** in adjacent Loma Machete quadrangle (Personius and others, 2000), and Cerro Conejo Member in adjacent Santa Ana Pueblo quadrangle (Personius, 2002). Mapped as lower member of unnamed lower formation of Santa Fe Group by Spiegel (1961) and as Zia Member of Santa Fe Formation by Kelley (1977). From highest to lowest, Cerro Conejo Member is herein subdivided into upper, middle, and lower informal subunits:

Upper subunit—Pink to very pale brown (7.5–10YR 8/4 and 10YR 7/4–5), fine- to coarse-grained feldspathic sandstone; subunit is primarily cross bedded and cross laminated but is locally horizontally laminated or massive; foresets usually less than 2 m high. Also contains <5 percent thin mudstone and local 1- to 2-m-thick, white (10YR 8/1) ash beds best exposed in southeastern part of quadrangle; ashes lack mafic minerals, have silty textures, and may be altered to a bluish white. Ashes may contain yellow (10YR 7/6) mottles that partly coat lamination plane surfaces or form 2- to 5-mm-thick bands. A sample from the stratigraphically highest ash located in sec. 7, T. 13 N., R. 3 E., 6–9 m below base of Arroyo Ojito Formation, yielded chemical fingerprint possibly correlative with a 10.83±0.03-Ma tephra (A. Sarna-Wojcicki, written commun., 1997, in Personius and others, 2000), or a 10.94±0.03-Ma tephra (A. Sarna-Wojcicki, written commun., 2001) from Snake River Plain/Yellowstone hotspot in southern Idaho. Another ash in this subunit, located in sec. 9, T. 14 N., R. 2 E. (sample locality M1), also has chemical and shard characteristics typical of Snake River Plain/Yellowstone hotspot sources; preliminary chemical matches are to 11.31±0.10-Ma tephra in the Aldrich Station section of western Nevada and Trapper Creek section of southern Idaho (A. Sarna-Wojcicki, written commun., 2001), and to an ash with very similar chemistry on north side of Jemez River (sample locality SPT8/26/97–1). However, the ash on north side of Jemez River was probably deposited in the middle subunit, so either the upper and middle subunits are diachronous or the chemical correlations are incorrect. Subunit is poorly indurated, easily eroded, and poorly exposed. Subunit correlates with unit **8** of Connell and others (1999) and is approximately 100–130 m thick

Middle subunit—Pink to very pale brown (7.5–10YR 8/4 and 10YR 7/4–5), fine- to medium-grained sandstone; reddish to reddish-brown sandy claystone and clayey sandstone make up as much as 10 percent by volume. Deposits form internally massive, thin to thick, tabular beds; minor horizontal or low-angle cross laminations occur in some sandstone beds. Subunit is fossiliferous, particularly in mudstone beds within pink and green sandstone intervals, and locally is ash-rich. A 60-cm-thick, greenish-gray ash altered to a soapy texture is located in sec. 3, T. 14 N., R. 2 E.; ash has 2–5 percent black dendritic minerals (probably manganese oxide) with long diameter of about 1 mm. This ash may correlate with "lower ash" in adjacent Cerro Conejo quadrangle (Koning and others, 1998) and with thick ash of unit **6c** of Connell and others (1999). Several ash outcrops on north side of Jemez River have similar soapy texture and black dendritic minerals; most are in single, 60- to 100-cm-thick thick beds, but westernmost outcrop in sec. 30 and 31, T. 15 N., R. 3 E. expose two ashes (upper 60-cm-thick ash and lower 30-cm-thick ash) separated by 3 m of sandstone. One ash from north side of Jemez River (sample locality SPT8/26/97–1) in sec. 32, T. 15 N., R. 3 E. has chemical and shard characteristics typical of Snake River Plain/Yellowstone hotspot sources; preliminary chemical matches are to 11.31±0.10-Ma tephra in the Aldrich Station section of western Nevada and Trapper Creek section of southern Idaho (A. Sarna-Wojcicki, written commun., 2001), and to an ash having very similar chemistry on south side of Jemez River (sample locality M1). However, the ash on south side of Jemez River was deposited in upper subunit, so either the middle and upper subunits are diachronous or chemical correlations are incorrect. Another prominent 1-m-thick ash bed near U.S. Highway 550 (sample locality MRGB–19–BNW) in southeast corner of quadrangle has chemical fingerprint very similar to a 11.19±0.10-Ma tephra from Trapper Creek section (A. Sarna-Wojcicki, written commun., 2001). Subunit generally is poorly indurated, is poorly to moderately exposed, and forms badlands topography. Subunit correlates with units 6 and 7 of Connell and others (1999) and is approximately 50–70 m thick

Lower subunit—Very pale brown (10YR 7/4–5), fine- to coarse-grained, subangular to subrounded, moderately well sorted lithic to feldspathic to quartzose sandstone interbedded with minor (< 5 percent) thinly bedded, red sandy mudstone. Sandstone lacks cemented, indurated beds and is commonly poorly exposed to covered. Subunit occurs in sec. 33 and 34 of T. 15 N., R. 2 E. and probably correlates with unit 5 of Connell and others (1999). Lower contact of the Cerro Conejo Member not observed, so thickness unknown

Tzcc$_i$ **Interbedded upper part of Cerro Conejo Member of Connell and others (1999) (upper Miocene)—**Pink to very pale brown (7.5–10YR 8/4 and 10YR 7/4–5), fine- to medium-grained, well-sorted sandstone and <10 percent very pale brown to light-yellowish-brown (10YR 6–7/4), thin- to thick-bedded mudstone; deposits similar to upper subunit of unit **Tzcc**. Forms tongues or lenses in lower Navajo Draw Member (unit **Tonl**) of Arroyo Ojito Formation; lenses are 30–60 m thick in western part of quadrangle (sec. 4 and 9, T. 14 N., R. 2 E.) and 90–105 m thick near center (sec. 25 and 36, T. 14 N., R. 2 E.) of quadrangle. Mudstones included in unit **Tzcc$_i$** resemble mudstones of the lower Navajo Draw Member (unit **Tonl**) but are too thin to differentiate at map scale

Tzcc$_c$ **Cerro Conejo Member of Connell and others (1999), cemented (upper and middle Miocene)—**Undivided very pale brown (10YR 8/2), fine- to medium-grained, cross bedded, well-sorted sandstone, pervasively cemented with silica and calcium carbonate in footwall of Santa Ana fault in northeast corner of quadrangle. Exposed thickness 60 m

Tzl **Chamisa Mesa and Piedra Parada Members, undivided (lower Miocene)—**Shown on cross section only; based on description of cuttings and interpreted geophysical log from Davis-Tamaya #1–Y exploratory well (D.J. Koning, written commun., 1999; Connell and Koning, 2001). Consists of very pale brown to light-gray to yellow (10YR 7/2–6), mostly medium- to coarse-grained, subrounded and frosted quartzose to feldspathic sandstone interbedded with minor clayey sandstone, claystone, or greenish silty sandstone; very sparse tephra or volcaniclastic clasts; locally cemented with calcium carbonate or iron oxides. Unit mapped to west of quadrangle as Chamisa Mesa and Piedra Parada Members of Zia Formation and interpreted there to reflect eolian dune, interdune, and fluvial environments (Galusha, 1966; Gawne, 1981; Koning and others, 1998; Pazzaglia and others, 1998, 1999). Thickness about 400 m as interpreted from Davis-Tamara #1–Y well (D.J. Koning, written commun., 1999; Connell and Koning, 2001) and about 680 m as interpreted from Santa Fe Pacific #1 well (Personius and others, 2000); wells are located 9 and 12 km, respectively, south of line of cross section

Tzlo **Lower part of Zia Formation and (or) older rocks (Miocene to upper Eocene?)—**Shown on cross section only; based on description of cuttings and interpreted geophysical log from Davis-Tamaya #1–Y exploratory well (D.J. Koning, written commun., 1999; Connell and Koning, 2001), located 9 km south of cross section. Includes two informal subunits. Upper subunit is pink to very pale brown (7.5YR–10YR 7/4), mostly fine- to medium-grained, subrounded, quartz-rich feldspathic sandstone containing local clay-rich zones. Lower subunit is reddish-yellow (5YR 7/4 to 7.5YR 6/6), fine- to coarse-grained, subrounded to rounded, quartz-rich lithic to quartzose sandstone that is more indurated than overlying strata; rock fragments are generally chert and intermediate to felsic hypabyssal intrusive or volcanic detritus. Unit correlations are uncertain. Upper and lower subunits may correlate with the Abiquiu Formation and unit of Isleta #2 of Lozinsky (1988), respectively (Connell and Koning, 2001). Alternatively, abundance of subrounded grains and similarity of geophysical logs in Tamara #1–Y and Santa Fe Pacific #1 wells suggest that both units may correlate with lower Zia Formation. Upper and lower subunits are 232–245 m and 223–236 m thick, respectively (corrected for dip), in Tamara #1–Y well (Connell and Koning, 2001)

Older Rocks

Tg **Galisteo Formation (Eocene)—**Shown on cross section only; based on description of cuttings and interpreted geophysical log from Davis-Tamaya #1–Y exploratory well (D.J. Koning, written commun., 1999; Connell and Koning, 2001), located 9 km south of line of cross section. Reddish-yellow, pink, and very pale brown (7.5YR–10YR 6–7/4–6) and light gray (10YR 7/1–2), subangular to subrounded lithic sandstone and gravelly sandstone; lacks volcanic detritus but may contain gray granitic fragments and chert. Thickness estimates include ≥175 m (Cather, 1992; Koning and others, 1998) in adjacent Cerro Conejo quadrangle, 205 m in Santa Fe Pacific #1 well (Black and Hiss, 1974; Lozinsky, 1988; Personius and others, 2000), and 327–345 m in Tamara #1–Y well (Connell and Koning, 2001)

KJu **Cretaceous and Jurassic rocks, undivided (Cretaceous and upper Jurassic)—**Shown on cross section only. Sedimentary rocks of upper Cretaceous Menefee Formation, Point Lookout Sandstone, Mancos Shale, Crevasse Canyon Formation, Niobrara Formation, Greenhorn Limestone, lower and upper Cretaceous Dakota Sandstone, and Jurassic Morrison Formation. Penetrated in Tamara #1–Y (Menefee Formation, D.J. Koning, written commun., 1999; Connell and Koning, 2001) and Santa Fe Pacific #1 (Black and Hiss, 1974) wells, located 9 and 12 km, respectively, south of line of cross section; total thickness of interval in Santa Fe Pacific #1 well is 1,160 m (Black and Hiss, 1974)

Contact—Dashed where approximately located; queried where inferred

Fault—Bar and ball on downdropped side (where known); tic indicates amount and direction of dip. Dashed where approximately located, dotted where concealed, queried where inferred

Fold—Showing trace of axial surface; dashed where approximately located. Large arrow shows direction of plunge

Anticline

Syncline

Aeromagnetic anomaly—Analysis by authors of high-resolution aeromagnetic data from U.S. Geological Survey and SIAL Geosciences, Inc. (1997); linear anomalies mark probable locations of faults buried by surficial deposits (Grauch and Millegan, 1998; Grauch, 1999)

Strike and dip of bedding

40 **Inclined**

Horizontal

Paleocurrent measurement—Arrow points in downstream direction

Tamara #1-Y **Selected well location—**Showing well name

Qesy/Qalo **Thin surficial deposit (upper symbol) covering older unit**

8h **Chronological sample locality—**Number referenced in text

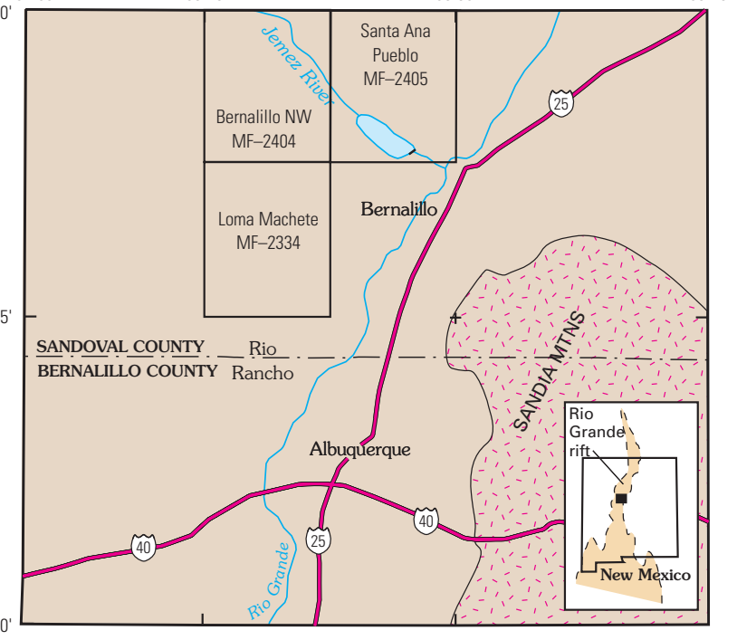
Tephra deposit

Table 1. *Correlation chart for alluvial deposits of the Jemez River (upstream is to left), indicated by map unit symbols.*

[Units in bold type shown on this map. Leaders (--) indicate that deposit not mapped in quadrangle]

Ponderosa quadrangle[1]	Jemez Pueblo and San Ysidro quadrangles[2]	**Bernalillo NW quadrangle**	Santa Ana Pueblo quadrangle[3]
Qt9	Qt6	**Qaj6b**	Qaj6
Qt7, Qt8	Qt5	**Qaj6a**	Qaj6
Qt5?	Qt4a?	**Qaj5**	Qaj5
Qt5?	Qt5a, Qt4a?	**Qaj4**	--
Qt4	Qt4	**Qaj3**	Qaj3
Qt3	Qt3	**Qaj2**	--
Qt2	Qt2	--	Qaj1

[1]Sources: Rogers (1996) and Rogers and Smartt (1996)
[2]Sources: Formento-Trigilio and Pazzaglia (1996, 1998), Formento-Trigilio (1997), Pazzaglia (1998), and Pazzaglia and others (1998)
[3]Source: Personius (2002)



INDEX MAP

Table 2. *Results of ^{40}Ar/^{39}Ar dating in Bernalillo NW quadangle.*

[All data are from L. Peters (written commun. to S.D. Connell, 2000; New Mexico Geochronological Research Laboratory Internal Report NMGRL-IR-67)]

Field sample No.	NMGRL[1] Lab Number	Sample locality (UTM coordinates, zone 13, NAD 1983)	Map unit	Description of sample locality	Mineral dated	Weighted mean age ± 2 sigma
11C[2]	50518	3921000 N; 344130 E	Tob	Single hornblende-bearing tephra clast in a bouldery channel deposit.	Single crystal biotite.	7.38±0.03 Ma
11E	50516	3920970 N; 342720 E	Tob	Channel deposit (≈4 m thick) of conglomerate and sandstone; upper 10–100 cm composed of pumice pebbles.	Single crystal sanidine.	7.02±0.06 Ma
8h-1	50485-01	3919210 N; 342704 E	Toc	Basalt cobble	Groundmass concentrate.	6.52±0.20 Ma[3]
8h-2	50486-01	3919210 N; 342704 E	Toc	Basalt cobble	Groundmass concentrate.	8.31±0.18 Ma[3]
8h-3	50487-01	3919210 N; 342704 E	Toc	Basalt cobble	Groundmass concentrate.	6.89±0.26 Ma[3*]

[1]New Mexico Geochronological Research Laboratory, New Mexico Institute of Mining and Technology, Socorro, N. Mex.
[2]Field sample number in NMGRL Internal Report is erroneously listed as "11W"
[3]Basalt samples yielded discordant age spectrums—all ages are approximate
*Integrated age, no weighted mean age assigned

DISCUSSION

The Bernalillo NW quadrangle is in the northern part of the Albuquerque basin, which is the largest basin or graben within the Rio Grande rift in New Mexico. The quadrangle is underlain by poorly consolidated sedimentary rocks of the Santa Fe Group, and was previously mapped in part or as a whole at scales of 1:190,000 (Spiegel, 1961; Kelley, 1977), 1:125,000 (Smith and others, 1970), and 1:24,000 (Manley, 1978). However, nomenclature of the Santa Fe Group used in these previous maps has recently undergone major modification (Smith and Lavine, 1996; Connell and others, 1999), which necessitated remapping of the quadrangle at a scale of 1:24,000.

STRUCTURE

The structural fabric of the quadrangle is dominated by dozens of generally north striking, east- and west-dipping normal faults associated with the Neogene Rio Grande rift. Many of these faults are spectacularly exposed in the badland topography south of the Jemez River. The north-striking faults are separated into eastern and western groups by a set of northeast-striking faults that form a 3-km-wide zone across the central part of the quadrangle.

A prominent structural feature, the north-trending Ziana anticline, was mapped across the central part of the quadrangle by Black and Hiss (1974) and Kelley (1977). In the southern part of the quadrangle and the Loma Machete quadrangle to the south (Personius and others, 2000), this structure separates opposing tilt domains (west-dipping to west and east-dipping to east) but does not have a well-defined fold axis. Personius and others (2000) renamed this structure the Ziana horst in the Loma Machete quadrangle to better reflect its primary origin in faulting, rather than folding. Near the boundary between the Loma Machete and Bernalillo NW quadrangles, the Ziana horst is broken into a series of fault blocks; these blocks have both east and west tilts and also include small antiforms (for example, in NE¼ sec. 1, T. 13 N., R. 2 E.) that may be reverse drag features. The Ziana horst may extend into a complexly faulted area in the southern part of the Bernalillo NW quadrangle as a heavily faulted antiform, but available bedding attitude data do not prove this inference. However, we have mapped a north- and northeast-striking, north-plunging anticline in the north-central part of the quadrangle that is roughly equivalent to the northern part of the Ziana anticline mapped by Black and Hiss (1974) and Kelley (1977). Poor bedrock exposures near the center of the quadrangle and lack of surface access prevent us from determining whether a continuous structure exists between the Ziana horst in the Loma Machete quadrangle and the anticline that we map in the north-central part of the Bernalillo NW quadrangle.

Two prominent, named faults are mapped in the quadrangle. The Zia fault of Kelley (1977) (Rincon fault of Manley, 1978) is present along the northwestern edge of the map area. This fault is well exposed in the adjacent Cerro Conejo quadrangle (Koning and others, 1998) and offsets Quaternary alluvium (unit **Qalo**) 50–70 cm (Manley, 1978) in sec. 8, T. 14 N., R. 2 E. Preliminary data from a trench study about 1 km west in the adjacent Cerro Conejo quadrangle indicate displacement on the Zia fault in the Holocene or late Pleistocene (McCalpin, 2000, 2001). The other prominent fault in the map area is the Santa Ana fault, which is in the northeast corner of the quadrangle. The Santa Ana fault is marked by a prominent silica- and calcium carbonate-cemented, erosion-resistant footwall whaleback of Cerro Conejo Member (unit **Tzcc$_c$**) that stands about 75 m above the surrounding topography. The Santa Ana fault has been mapped as extending as far south as the Jemez River (Manley, 1978) and beyond (Kelley, 1977), but our mapping and analysis of high-resolution aeromagnetic data (U.S. Geological Survey and SIAL Geosciences, Inc., 1997) indicate that the fault extends only about 1 km south of the whaleback.

DEPOSITIONAL ENVIRONMENTS AND CONTROLS ON SEDIMENTATION

Zia Formation

The upper subunit of the Cerro Conejo Member of the Zia Formation of Connell and others (1999) is interpreted to represent moderate- to high-energy eolian and fluvial environments. Evidence for fluvial environments includes (1) scour surfaces with centimeter-scale rip-up clasts of previously deposited cohesive sand; (2) lenticular lenses of moderately sorted, coarse-grained sand that are as much as 15 cm thick; (3) clay beds draped over dune forms; and (4) channels as much as 1 m deep. The middle and lower subunits of the Cerro Conejo Member represent lower energy, suspended-load fluvial and eolian environments. Low-energy conditions are indicated by the lack of coarse sand and lack of tall foresets in cross strata. Instead, massive, fine to medium sand along with minor sandy clay beds dominate. Regionally, voluminous volcanic eruptions deposited abundant ash in the middle subunit.

Although the exposed parts of the Cerro Conejo Member do not noticeably change character across faults in the Cerro Conejo (Koning and others, 1998; Connell and others, 1999) and Bernalillo NW quadrangles, analysis of subsurface data from the Davis-Tamara #1–Y well (D.J. Koning, written commun., 1999; Connell and Koning, 2001) suggests substantial thickening of the lower Zia and (or) older rocks (units **Tzl** and **Tzlo** in cross section) across major structures in the southern part of the quadrangle. These relations suggest significant tectonic activity and local erosion in this part of the map area during Oligocene through early Miocene time (Connell and Koning, 2001).

Arroyo Ojito Formation of Connell and others (1999)

Gravel channels in the Navajo Draw Member indicate a moderate-energy, mixed bedload-suspended load fluvial environment. Aside from tongues or lenses of the Cerro Conejo Member of the Zia Formation near its base, eolian sand is rare in most of the Navajo Draw Member except in the lower part of the member (unit **Tonl**) along the southern margin of the quadrangle. A noteworthy change in color, composition, and texture occurs between the Navajo Draw Member and the Cerro Conejo Member. This change probably signals a change in provenance or paleo-flow conditions. The gravel composition of the Navajo Draw Member in this quadrangle is similar to that described in the Cerro Conejo quadrangle (Koning and others, 1998; Connell and others, 1999) and probably represents the erosion or unroofing of Abiquiu Formation and Mesozoic rocks from the Sierra Nacimiento and western Jemez Mountains. Southeast paleocurrent directions in the quadrangle are compatible with this interpretation. The reddish zones in the Navajo Draw Member (unit **Tonlr** and **Tonm**) may have been derived from the north-northeast because these rocks are significantly more abundant and thicker in the quadrangle than to the west (Koning and others, 1998; Connell and others, 1999). Two observations suggest extensional faulting during the deposition of the Navajo Draw Member. First, units **Tonlr** and **Tonm** are localized in numerous fault blocks east of the Zia fault in the western part of the quadrangle; these red beds within the Navajo Draw Member are rare west of the Zia fault and where present are only 1–2 m thick (Koning and others, 1998; Connell and others, 1999). Second, we have observed distinct sedimentologic changes in the upper Navajo Draw Member in the hanging wall immediately adjacent to the Zia fault. For example, within ≈150 m of the Zia fault in sec. 8, T. 14 N., R. 2 E., the unit changes from typical pale yellow-brown, thin- to thick-bedded sandstone to orange-brown, very thin bedded to medium-bedded, fine-grained sandstone and mudstone. A similar fining of the upper Navajo Draw Member in the hanging wall immediately adjacent to the San Ysidro fault also was observed in the adjacent Cerro Conejo quadrangle (Koning and others, 1998).

Moderate-energy, mixed bedload-suspended load fluvial environments persisted during deposition of the Loma Barbon Member. However, a distinct change in sediment composition and color occurs between the Loma Barbon and Navajo Draw members—the Loma Barbon Member is more feldspathic and contains more granite than the underlying Navajo Draw Member. This change probably represents the unroofing of the harder granite and remaining Pedernal Chert Member of the Abiquiu Formation from the Sierra Nacimiento and western Jemez region after removal of the softer upper Abiquiu Formation and other Mesozoic sedimentary rocks. Paleocurrent directions in the Loma Barbon Member indicate southeast-directed flow and are consistent with this interpretation. The faulting that is interpreted during deposition of the Navajo Draw Member continued through the deposition of the Loma Barbon Member. For example, in the adjacent Cerro Conejo quadrangle, the Loma Barbon Member thickens slightly (≈28 m) eastward across the Zia fault (Koning and others, 1998).

The Ceja Member is dominated by fluvial-bedload sedimentary rocks (pebble to boulder conglomerate and sandstone) and is ubiquitous in the northwestern Albuquerque Basin. This member heralds a major high-energy aggradational phase across the region. Continued faulting during deposition of the Ceja Member created minor horsts and grabens, caused significant variations in the thickness of the Ceja Member, and resulted in the deposition of fault-related sedimentary wedges (unit **Tocf**) that overlie the pinkish-gray conglomerate of unit **Toc**.

Quaternary Deposits

The Jemez River began to incise underlying strata prior to eruption of the 1.6-Ma (Izett and others, 1994) Bandelier Tuff (Rogers, 1996; Rogers and Smartt, 1996, Formento-Trigilio and Pazzaglia, 1996, 1998; Connell and others, 1999; Cole and others, 2001). Consequently, tributary arroyos began to deeply incise and erode the Santa Fe Group in the quadrangle in response to this drop in base level. Intermittently during this erosion, changes in the balance of stream power and sediment load (see, for comparison, Bull, 1991), probably driven by changes in climate, allowed widespread aggradation of alluvial aprons and alluvium underlying terraces along major arroyo systems and the Jemez River. These aggradational events are represented by units **Qalo** and **Qaly** along arroyos and units **Qaj2** through **Qaj6** along the Jemez River. With the exception of the Zia fault, these deposits bury faults and indicate only minor surface faulting during the Quaternary on most structures in the quadrangle.

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